Actel Firmware Usermanual

Document Name:	actel_usermanual.doc
Document Revision:	0.2
Firmware Revision:	1.3
Date:	Created on 8/9/2006 9:15:00 AM
Author:	Johan Alme (JA), Ketil Røed (KR)
	Johan.alme@ift.uib.no
	ketil.roed@ift.uib.no
Last Saved By:	Johan Alme, May 8, 2007

ACTEL FIRMWARE USERMANUAL 1

1 DOCUMENT CONTROL 3

1.1 REVISION HISTORY 3
1.2 REFERENCES 3
1.3 CVS 3
1.4 DOWNLOADS 3

2 OVERVIEW 4

3 ACTEL FIRMWARE GLOBAL REGISTERS 5

3.1 COMMAND REGISTER STRUCTURE 6
3.2 STATUS REGISTER STRUCTURE 7
3.3 ERROR REGISTER STRUCTURE 7
3.4 VERSION NUMBER REGISTER STRUCTURE 7

4 RCU-SH AND DCS-RCU OPERATION MODES 7

4.1 MEMORY MAPPED MODE 8
4.2 FLASH MODE 10
4.3 SELECTMAP MODE 11

5 CONFIGURATION OF THE EXTERNAL FLASH DEVICE 11

5.1 USING THE SOFTWARE TOOLS 11
5.1.1 Prepare for initial configuration & scrubbing 12
5.1.2 Prepare for frame by frame readback and verification 13

6 ADVANCED USER 15

6.1 SOFTWARE TOOLS 15
6.1.1 Rcuflashprog -The RCU Flashprogramer 15
6.1.2 Framegen – The framegenerator 16
6.1.3 Framever 17
6.2 HOW TO READ OUT A SINGLE FRAME FROM THE SELECTMAP INTERFACE 17
6.3 ARCHITECTURE OF EXTERNAL FLASH DEVICE 21
6.3.1 Setting up Flash device for initial configuration and scrubbing 22
6.4 PREREQUISITES OF ACTIVE PARTIAL RECONFIGURATION 25

1 Document control

1.1 Revision history

Rev.	Rev. date	Document status	Responsible
0.1	02.11.06	First draft	JA/KR
0.2	08.04.07	Small error corrections on address mapping	JA
0.3			
0.4			
0.5			

1.2 References

Ref. No.	Doc. Name.	Rev / Rev date	Title
1	Actel specification.doc	0.5/09.08.06	Digital module requirement specification
2	Ug012.pdf	V4.0/March 05	Virtex-II Pro and Virtex-II pro X User Guide
3	Ds083.pdf	V4.5/Oct 05	Virtex-II Pro and Virtex-II pro X Platfrom FPGAs: Complete Data Sheet
4	MX29LV640BT-BB-1.2.pdf	V1.2/Sep 95	MX29LV640BT/BB 64M-BIT [8Mx8/4Mx16] single voltage 3V Only Flash Memory Data Sheet
5	ProASICPlus_DS.pdf	V5.0/Aug 05	ProASICPLUS Flash Family FPGAs Data Sheet

1.3 CVS

This document and the complete project are checked in to the ALICE CVS database at the University of Bergen.

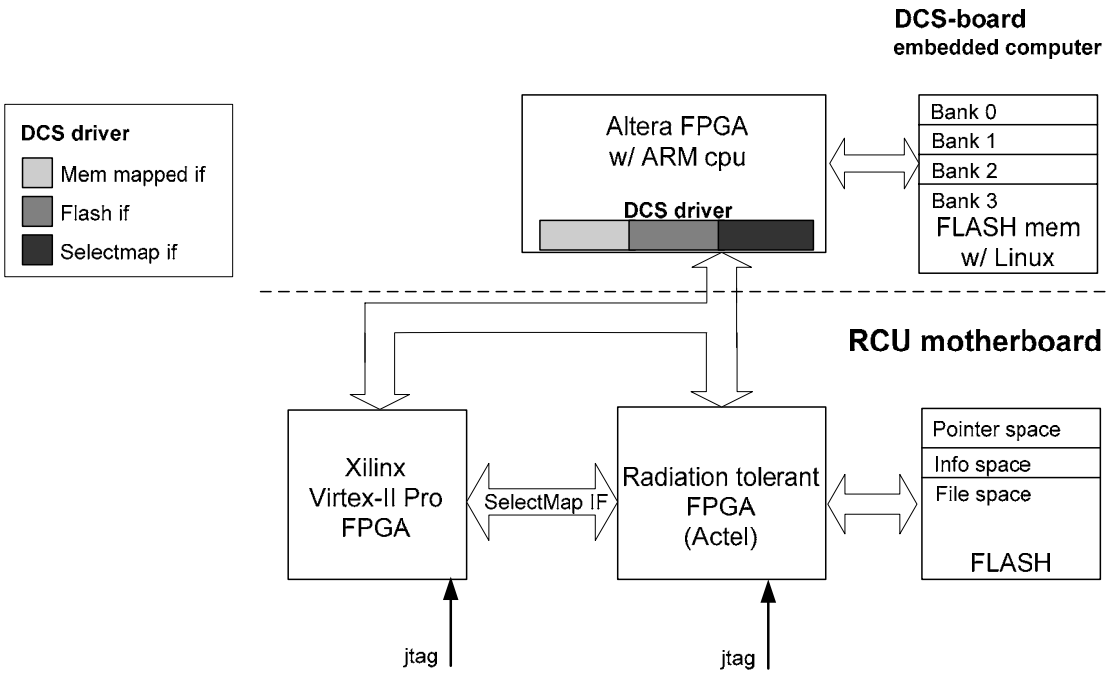
Url: http://web.ift.uib.no/kjekscgi-bin/viewcvs.cgi/vhdlcvs/

Module name is *rcu_cpld*.

1.4 Downloads

Visit http://web.ift.uib.no/~kjeks/wiki for future updates on this document, programming files and detailed documentation.

2 Overview



The solution on the RCU boards consists of a flash-based Actel FPGA that communicates with the SelectMAP Interface on the Xilinx Virtex-II pro, and an on-board Flash Memory. The Actel FPGA has a communication interface upwards to the DCS board. All needed configuration files for the Xilinx are stored on the Flash Memory. Due to the limited access to the Actel for later firmware updates, the main focus in the development of the firmware has been robustness. Thus as much functionality as practical possible is handed over to the DCS board.

3 Actel firmware global registers

Register name	Size (bit)	Address	Type [1]	Description
Command	1	0xB000	W	Writing to this register triggers a command execution. See Table 3.2 for available commands
Command_SM	12	0xB002	W	Writing to this register triggers a command execution for the SelectMAP. See Table 3.3 for available commands
Actel_Reset	1	0xB003	T	Asynch reset to Actel device
Status	12	0xB100	R	Status Register. Table 3.4
Error	8	0xB101	R	Error Register. Table 3.5
Version_Number	16	0xB102	R	Firmware version: Table 3.6
Input_Data	16	0xB103	RW	Data to write to Actel, decided by command how it should be interpreted
RB_ErrCnt	16	0xB104	R	Number of Errors found by readback and verification of Xilinx Configuration Memory
RB_Err_FrameNumber	12	0xB105	R	Last frame number with error (as given by the sequence stored in the Flash memory)
RB_FrameNumber	12	0xB106	R	Last frame being verified (as given by the sequence stored in the Flash memory)
RB_numOfCycles	16	0xB107	R	Number of times a complete Frame by Frame readback (all frames) has been done.
Stop power up Code	4	0xB112	W	Writing X"A" to this register prevents the Actel from trying to automatically configure the Xilinx if sm_done is low
Flash_Interface _Memory	512x16	0xB200 – 0xB3FF	RW	RAM block used for Flash Communication
SelectMAP_Interface _Memory	512x16	0xB400 – 0xB5FF	RW	RAM block used for SelectMAP Communication

Table 3.1: Externally accessible registers. Registers 0xb104 through 0xb107 are referred to as information registers.

[1] Legend: W=write, R=read, T= write trigger (not physical registers)

3.1 Command Register Structure

The normal operation is command based. This means that most functionality is controlled by command registers that is made available for the DCS board. In addition an input data register is used as a configuration register for some of the commands.

Command	Value	Data register (0xB103)	Description
CLEAR_ERROR	0x1	Not Used	Clears error register, and brings FW out of an illegal state. Must be done if error has occurred.
CLEAR_STAT	0x2	Not Used	Clears status register and counters
INIT_CONFIG	0x4	Not Used	Initial configuration of Xilinx from Flash
SCRUB	0x10	Not Used	Reconfigures Xilinx one time.
SCRUB_CONT	0x20	Num of times to run. If zero then run continuously until abort.	Scrub Continuously from Flash
RBFRAME	0x100	Not Used	Read back single frame from Xilinx and clear error if found.
RBFRAME_CONT	0x200	Num of times to run. If zero then run continuously until abort.	Continuously read back Xilinx and clear error if found
ABORT	0x8000	Not Used	Aborts ongoing operation

Table 3.2: Command Register Codes (0xB000). Used for executing the main tasks of the Actel firmware.

Command SM	Value	Data register (0xb103)	Description
INIT_XIL	0x1	Not Used	Do init procedure of Xilinx. Will erase the content of the Xilinx configuration memory.
STARTUP_XIL	0x2	Not Used	Do startup procedure of Xilinx
WRITE_XIL	0x4	Data to be written	Write a 16 bit word to SelectMAP IF
READ_XIL	0x8	Number of 16 bit words to read. If this register is 0, only 1 read op is performed.	Issue a read command of SelectMAP IF. (Only effective if certain write commands been issued first)
ABORT_XIL	0x10	Not Used	Issue abort sequence

Table 3.3: Command_SM Register Codes (0xB002). The SelectMAP Command register is used for executing atomic tasks on the SelectMAP bus.

3.2 Status register structure

Name	Bit index	Description
Value of the Stop power up code register (0xb112)	11:8	0xA: Automatic configuration of Xilinx is deactivated
Null pointer in flash	7	0: Flash contains a pointer value 1: Flash contains no pointer value
Busy	6	0: Configuration controller ready to received command 1: Configuration controller is busy with ongoing task/command
Not used	5	NA
Smap busy	4	0: SelectMAP interface module ready 1: SelectMAP interface busy
(Last) Active code	3:0	Contains the last task carried out by the configuration controller 0xA: Initial configuration 0xB: Scrubbing 0xC: Scrubbing continous 0xD: Read back frame and verify 0xE: Read back frame and verify continuous

Table 3.4: Status register (0xB100).

3.3 Error register structure

Name	Bit index	Description
SelectMAP RAM parity error	7	0: No parity error 1: Parity error detected in SelectMAP RAM
Flash RAM parity error	6	0: No parity error 1: Parity error detected in Flash RAM
Not used	5:3	NA
Smap unknown command	2	0: Legal command 1: Unknown command issued to Smap interface
Smap busy not asserted	1	0: No errors 1: Busy on SelectMAP interface was not actived
Smap Done failed	0	0: Done detected after configuration of Xilinx 1: Failed to detect Done from SelectMAP interface.

Table 3.5: Error register (0xB101)

3.4 Version number register structure

Name	Bit index	Description
Major number	15:8	For firmware version v1.03 major number this register will contain the value 0x103
Minor number	7:0	

Table 3.6: Version number register (0xB103)

4 Rcu-sh and DCS-RCU operation modes

The RCU Shell is a small command-line software for communicating with the firmware on the RCU motherboard, that is the Xilinx Virtex-II and Actel firmware. It is started by simply typing 'rcu-sh' at the command-line. This will bring you to the

shell mode, where different types of commands can be executed. Issuing a command in the rcu-sh software can be done either by writing *rcu-sh <command>* in the dcs board linux terminal prompt, or by first starting the rcu-sh software and then write the <command>.

The RCU motherboard can be operated in three different modes.

1. Memory mapped mode
2. SelectMAP mode
3. Flash mode

The default mode is memory mapped mode, which gives you direct memory access of the registers in the FPGAs on the RCU motherboard.

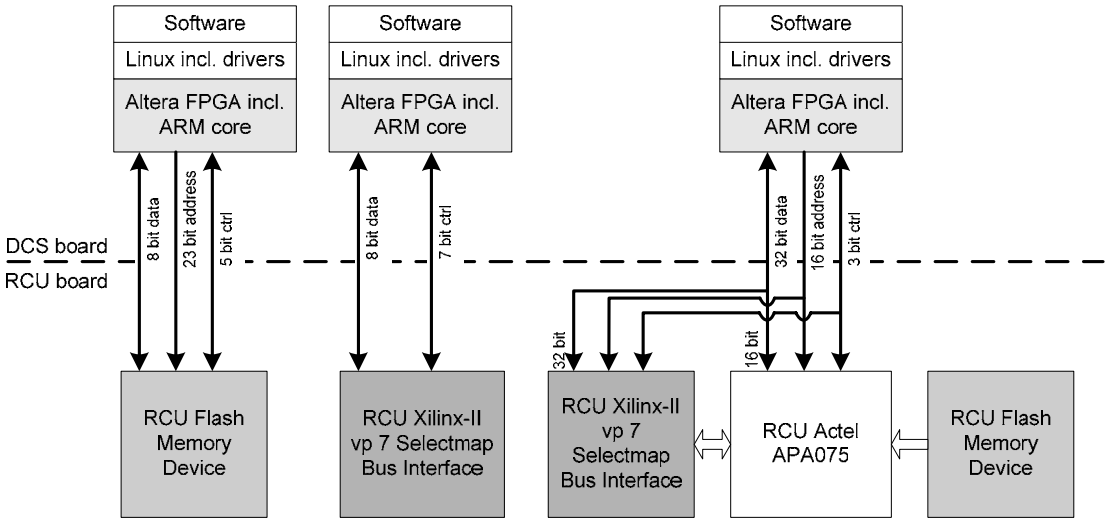


Figure 4-1: Sketch showing a logical model of the three modes.From left to right Flash mode, SelectMAP mode and Mempry mapped mode (normal operation). In Memory Mapped Mode the RCU Flash Memory is read-only.

Flash mode gives the dcs board direct control of the flash memory on the RCU motherboard, while SelectMAP mode gives the dcs board direct control over the SelectMAP interface of the Xilinx Virtex-II on the RCU motherboard.

4.1 Memory mapped mode

Normal operation in memory mapped mode assumes that the flash is setup with correct pointer information and configuration files and frames. If the on board Flash device contains no data or incorrect data, section 5 provides more information on how to proceed. Table 4.1 lists the general commands used to write to and read from register and memory locations in the Actel firmware.

Option	Command
Get help on commands:	`help`
Single write	`w<rite> 0x[address] 0x[data]`
Multiple write	`w<rite> 0x[address] <num> 0x[data]` num = number of sequental addresses to write the given data to
Single read	`r<ead> 0x[address]`
Multiple read	`r<ead> 0x[address] [num]` num = number of sequental addresses to read

Table 4.1: General rcu-sh commands

The most frequent used commands during normal operation are:

Reading the status, error and other important registers	
• By reading back register 0xb100 through 0xb107	`r 0xb100 8`

Disabling the automatic configuration feature	
• By writing 0xa to the stop power up register	`w 0xb112 0xa`

Clearing error and status registers	
• Clearing error register	`w 0xb000 0x1`
• Clearing status register and information registers (0xb100 & 0xb104-0xb107)	`w 0xb000 0x2`

Complete initial configuration of the Xilinx FPGA	
• By single command from DCS board	`w 0xb000 0x4`
• On power up of the board	
• If Xilinx is not configured and the stop code 0xa is not written to the stop power up code register 0xb112.	

Active Partial Reconfiguration (Scrubbing) of the complete configuration memory in the Xilinx. It is issued by a single command from the DCS board and runs either as:	
• a single reconfiguration	`w 0xb000 0x10`

• continuously running a given number of cycles or until an abort is issued
 	
The given number of cycles `[num]` until an abort must first be written to the data register. If the data register stores the value 0 the operation will run continuously until an abort is issued.
	`w 0xb000 0x20`
	
	`w 0xb103 0x[num]`

Frame by frame readback and verification, and reconfiguration of a frame if an error is discovered. There are two possible ways of operation	
• stepping through one single frame at the time by a DCS command, making it possible to read the contents of the memories from DCS board for more thorough error logging and handling	`w 0xb000 0x100`

• continuously running a given number of cycles or until an abort is issued
 	
The given number of cycles `[num]` until an abort must first be written to the data register. If the data register stores the value 0 the operation will run continuously until an abort is issued.
	`w 0xb000 0x200`
	
	`w 0xb103 0x[num]`

Delete the configuration memory of the Xilix Virtex-II FPGA	
• this command activates the prog_b line of the SelectMAP interface, thereby deleting the content of the configuration memory of the Xilinx. This only works when *0xa* is written to the *stop power up register 0xb112* to disable automatic reconfiguration of the Xilinx.	`w 0xb002 0x0x1`

Some additional commands exists which are related to communication with the SelectMAP interface. These commands are recommended use for advanced users only.

Option	Command
Issue startup procedure of Xilinx	`w 0xb002 0x2`
Write a 16 bit word to the SelectMAP IF by first writing to the data register (0xb103) and then issuing the command	`w 0xb103 0x[data]` `w 0xb002 0x4`

Issue a read from the SelectMAP IF by first writing the number of words to read in the data register (0xb103). If the data register contains 0, only 1 word is read
 	
The result will be placed in the actel internal SelectMAP user memory (RAM) and can be read out by issuing the command
	`w 0xb113 0x[num]`
	`w 0xb002 0x8`
	
	`r 0xb400 [num]`
	`[num]= number of words to read`

Issue the SelectMAP abort sequence	`W 0xb002 0x10`

Table 4.2: Advanced commands related to the SelectMAP interface

4.2 Flash mode

In this mode the firmware on the DCS board gets direct access to the Flash device control and data bus interface. The following options are available:

Option	Command
Enable flash mode	`flash enable`
Disable flash mode	`flash disable`
Get help on commands:	`flash help`
Write to single address in flash:	`flash write 0x[address] 0x[data] [num]` num = number of sequental addresses to write the given data to
Write a file from a start address in the flash:	`flash write [-s] 0x[address] file [size]` -s = byteswap enabled size = number of 16 bit words to write to the flash from beginning of file.
Erase complete flash:	`flash erase all`
Erase sector:	`flash erase sec 0x[sector address]`
Read single address from flash	`flash read 0x[address] [num]` num = number of sequental address to read from the given address.
Verify content of the flash memory	`flash verify 0x[address] file` Verifies that the content of the flash from the given address matches the content of the given file.

Table 4.3: Available rcu-sh commands in FLASH mode

The command interface to the Flash device is equal to normal operation of rcu-sh only typing the word *flash* in front of the command.

When writing to the external flash device it is important to remember that you can only write zeros – not ones – to the flash memory. This means that if something wrong is written, then one must erase the sector and rewrite all what is written into it. It is also *very* important to not overwrite anything in the areas of the programming files, as this can cause damage to the Xilinx when configuring it.

4.3 SelectMAP mode

In this mode the firmware on the DCS board gets direct access to the SelectMAP interface. For the moment this mode only supports initial configuration using the following command sequence:

```
1.  rcu-sh sm enable
2.  cat <bitfile.bit> > /dev/virtex/
3.  rcu-sh                          sm                                  disable
```

5 Configuration of the External Flash Device

The on board Flash memory device plays a key role in the proper operation of the Actel firmware. Without a correct configuration of this Flash memory the Actel firmware will not be able to carry out the main tasks of initial configuration, scrubbing and frame by frame readback and verification.

The external flash device can be configured using a combination of the rcu-sh software and/or other dedicated software tools. Section 5.1 describes the approach to configure the external flash device using the dedicated software tools. Section 6.1 gives a detailed description of the software tools.

5.1 Using the software tools

There are 2 available software tools for frame generation and flash programming:

- **Framegen** – reads back frame data via the SelectMAP interface and generates the correct frame files to be programmed to the flash
- **Rcuflashprog** – programs the initial configuration file, the scrubbing file and the frame files to the correct locations in the flash

The rcuflashprog is used together with a configuration file called *flashconf.txt*. This file contains different parameters that can be set according to which operation that will be carried out. That is, one can choose to program the configuration file, the scrubbing file, or the frame files separately, or a combination of these files. This is done by setting the different enabling parameters connected to the respective files to either *true* or *false*.

5.1.1 Prepare for initial configuration & scrubbing

Software tools	Configuration files	Comments
Rcuflashprog	Flashconf.txt Rcu.bit (or other confirguration file) Rcu_apr.bit (or other scrubbing file)	The default setting is to erase the full content of the flash

Enable the *init program file* and *scrubbing file* settings and disable the *frame file* settings in the *flashconf.txt* file:

```
enable_icfile = true(enable programming of initial configurationfile)
enable_scfile = true (enable programming of scrubbing file)
enable_frfiles = false (disable programming of frame files)
```

The path and filename have default settings and must be changed if other paths or filenames are used. It is however not recommended to change any other default values such as for instance the start addresses. This may lead to incorrect configuration of the flash device and possible failure in the firmware operation.

```
----------RCU Flashprogramer config file--------------------
#enable erase
enable_erase = true
#init program file
enable_icfile = true
path_icfile = /mnt/dcsshare/
name_icfile = rcu.bit
startaddr_icfile = 8000h

#scrubbing file
enable_scfile = true
path_scfile = /mnt/dscshare/
name_scfile = rcu_apr.bit
startaddr_scfile = 60000h

#frame file
enable_frfiles = false
path_frfiles = /mnt/dcsshare/
name_rawframefile = frame$.hex
name_readframefile = r_frame$.hex
name_writeframefile = w_frame$.hex
framesfile = frames.txt
startaddr_frfiles = 100000h
frame_offset = 2h
header_size_read = 1Bh
footer_size_read = 0Bh
-------------------------------------------------------------
```

Save changes and type the command: **"./rcuflashprog flashconf.txt"** in the command prompt. The file(s) will now be programmed to the flash. To configure the Xilinx Virtex-II with the new initial configuration file type the command:
"rcu-sh w 0xb000 0x4" in the command prompt.
See section 6 for information on the scrubbing feature of the firmware.

5.1.2 Prepare for frame by frame readback and verification

Software tools	Configuration files	Comments
Framegen	frames.txt read_header.txt read_footer.txt write_header.txt write_footer.txt	The Xilinx virtex-II must be configured with the proper firmware
Rcuflashprog	Flashconf.txt Rcu.bit (or other configuration file)* Rcu_apr.bit (or other scrubbing file)* frames.txt frame$.hex r_frame$.hex w_frame$.hex	The default setting is to erase the full content of the flash.

*Optional: the programming of the initial configuration file or scrubbing file can be disabled.

5.1.2.1 Framegen

In order to prepare for frame by frame readback and verification the different frame files must be generated. This is carried out by the framegen software tool. It reads out the frames specified in the *frames.txt* file from the Xilinx Virtex-II. The frames are stored as hex files in 3 different groups:

- original frame data: *frame$.hex*
- read frame data: *r_frame$.hex* (*read_header.txt* & *read_footer.txt* are added)
- write fram data: *w_frame$.hex* (*read_header.txt* & *read_footer.txt* are added)

See section 6.1.2 for more information about the configuration files.

Before the framegen software is started make sure that the Xilinx Virtex-II is configured with the correct firmware. It is also important to check if you can communicate with the Actel Device and the Flash Device. If you get errors when doing this, the Xilinx DCS interface is not correct.

Start the framegen software with the command:

"./framegen frames.txt read_header.txt read_footer.txt write_header.txt write_footer.txt"

Depending on the number of frames to be generated (specified in *frames.txt*) this operation may take several minutes.

5.1.2.2 Rcuflashprog

Enable the *frame file* settings in the *flashconf.txt* file:
enable_frfiles = true

As for initial configuration and scrubbing use default values unless other paths and filenames are used.

Save changes and type the command: **"./rcuflashprog flashconf.txt"** in the command prompt. The file(s) will now be programmed to the flash. To configure the Xilinx Virtex-II with the new initial configuration file type the command:
"rcu-sh w 0xb000 0x4" in the command prompt. The Xilinx will now be programmed. See section 6 for information on the frame by frame readback and verification feature of the firmware.

6 Advanced User

6.1 Software tools

The Actel firmware gives the 3 options of initial configuration, scrubbing and frame by frame readback and verification.

Operation	Need file(s) in flash	Software tool
Initial configuration	Full configuration bit file	Rcu-sh Rcuflashprog*
Scrubbing	Scrubbing configuration bit file	Rcu-sh Rcuflashprog* Rcubitfileprog
Frame by frame R&V	Write frame files Read frame files	Framegen* Rcuflashprog* framever

Figure 6-1: The table lists the different software tools that can be used to configure the external flash device.

6.1.1 Rcuflashprog -The RCU Flashprogramer

The RCU Flash Programer is a Tool for programing the RCU Flash memory.

It is configurable through a config file which can be specified as a parameter.
"./rcuflashprog flashconf.txt"

An example of the configuration file can be found at the end of this README file.

For the initial config:
the initial configurationfile and the path to the initial configurationfile have to be set.
Also the startaddress for the initial configuration.

For the scrubbing:
The scrubbingfile and the path to the scrubbingfile have to be set, also the the start address for the scrubbing.

For the flash programing of the frames:
The path for the framefiles has to be set, also there have to be all the frames specified in the framesfile.
the three "name_" variables define the filename of the framefiles. The $ is therefore replaced with "X.Y.Z" where X is the Block, Y is the Major and Z the Minornumber.
The startaddress has to be defined, also the size of the readheader and the readfooter.

```
----------RCU Flashprogramer config file--------------------
#init program file
enable_icfile = true
path_icfile = /mnt/kjekspc4/dominik/bin/rcuflashprog/
name_icfile = initconfig.bit
startaddr_icfile = 0h

#scrubbing file
enable_scfile = true
path_scfile = /mnt/kjekspc4/dominik/bin/rcuflashprog/
name_scfile = scrubbing.bit
startaddr_scfile = 60000h

#frame file
enable_frfiles = true
path_frfiles = /mnt/kjekspc4/dominik/bin/rcuflashprog/
name_rawframefile = frame$.hex
name_readframefile = r_frame$.hex
name_writeframefile = w_frame$.hex
framesfile = frames.txt
startaddr_frfiles = 100000h
frame_offset = 2h
header_size_read = 1Bh
footer_size_read = 0Bh
------------------------------------------------------------
```

6.1.2 Framegen – The framegenerator

In order to prepare for frame by frame readback and verification the different frame files must be generated. This is carried out by framegen software tool.

The Framegenerator is a Tool for reading out frames from Xilinx configuration memory.

To run it 5 input files are needed:

- Frames file (i.e. frames.txt)
- Read header file (i.e. read_header.txt)
- Read footer file (i.e. read_footer.txt)
- Write header file (i.e. write_header.txt)
- Write footer file (i.e. write_footer.txt)

These files have to be given to the program on startup as parameters, i.e.:
"./framegen frames.txt read_header.txt read_footer.txt write_header.txt write_footer.txt"

The frames file contains the framenumbers coded in Block, Major and Minornumber. The syntax in the frames file is like this: "Block;Major;Minor;"

i.e.:

0;5;3;
0;5;4;

The header and footer files contain the commands to be executed before/after reading of a frame. Also this data is included in the created readback files. The addresses of the frames have to be inserted as variables into this file ("frame_addr31_16" and "frame_addr15_0"). The proper addresses for the frame will be inserted here by the program.

For every frame it creates three files:

- one file with the raw readback data
- one file with the read header before the data and the read footer after the data
- one file with the write header before the data and the write footer after the data

6.1.3 Framever

The framever is used to run a more thorough readback and verification operation from the DCS board. The tool makes it possible to the location of the actually SEUs within the individual frames.

The tool will not be discussed in this version of the user manual.

6.2 How to read out a single frame from the SelectMAP interface

A full frame read back via the SelectMAP interface carry out by first writing a sequence of header data to the SelectMAP interface, then reading back the frame content before closing with a sequence of footer data. The header and footer data are special commands for preparing the SelectMAP interface for a frame read back

```
FFFFFFFF    #
AA995566    # Sync word
30008001    # Type 1 header: Write 1 word to cmd-register
00000007    # Reset CRC
30016001    # Type 1 header: Write 1 word to frame-length register
00000069    # Set frame length
30008001    # Type 1 header: Write 1 word to cmd-register
00000004    # Read configuration data command
30002001    # Write frame address command
$frameaddr  # Frame address (ex: clb – major 5 – minor 3)
28006000    # Type 1 header: Read from Configuration Out reg. (FDRO)
480000D4    # Type 2 header: Read 212 words from FDRO
20000000    # NOOPs to flush the register
20000000    #
```

Table 6.1: Read frame header. This table is based on table 4-37 in the Virtex-II FPGA user guide (Ref No. 2), without the commands related to the shutdown.

```
30008001    # Type 1 header: Write 1 word to cmd-register
00000007    # Reset CRC
30008001    # Type 1 header: Write 1 word to cmd-register
0000000D    # de synch interface
20000000    # NOOPs to flush the register
20000000    #
```

Table 6.2: Read frame footer. This table is based on table 4-37 in the Virtex-II FPGA user guide (Ref No. 2), without the commands related to the shutdown.

In between the header and footer the read back frame file is stored. The data must be ordered following a Big Endean 16 bit system.

The frames have the following address composition:

	BA	MJA	MNA	Byte number
31:27	**26:25**	**24:17**	**16:9**	**8:0**
00000	XX	XXXXXXXX	XXXXXXXX	000000000

Table 6.3: Virtex-II Pro frame address composition

See the Virtex-II FPGA user guide (Ref No. 2) for more information on addressing the different frames and reading and writing frame data.

In order to write data to the SelectMAP interface the following rcu-sh commands are use:

```
W 0xb103 0x[data] (write data to actel data register)
W 0xb002 0x4      (issue a write of data to the SelectMAP IF)
```

In Table 6.4 an rcu-sh script example is given for reading out a single frame. This example is for a CLB (BA: 00) with MJA 3 and MNA 2 which gives the address 0x00060400.

```
#write header commands
w 0xb103 0xffff
w 0xb002 0x4
w 0xb103 0xffff
w 0xb002 0x4
w 0xb103 0xaa99
w 0xb002 0x4
w 0xb103 0x5566
w 0xb002 0x4
w 0xb103 0x3000
w 0xb002 0x4
w 0xb103 0x8001
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x0007
w 0xb002 0x4
w 0xb103 0x3001
w 0xb002 0x4
w 0xb103 0x6001
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x0069
w 0xb002 0x4
w 0xb103 0x3000
w 0xb002 0x4
w 0xb103 0x8001
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x0004
w 0xb002 0x4
w 0xb103 0x3000
w 0xb002 0x4
w 0xb103 0x2001
w 0xb002 0x4
#[$frame_addr32_16]
w 0xb103 0x0006
w 0xb002 0x4
#[$frame_addr32_16]
w 0xb103 0x0400
w 0xb002 0x4
w 0xb103 0x2800
w 0xb002 0x4
w 0xb103 0x6000
w 0xb002 0x4
w 0xb103 0x4800
w 0xb002 0x4
w 0xb103 0x00d4
w 0xb002 0x4
w 0xb103 0x2000
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x2000
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
#issue multiple read  212x2=424 (0x1a8) 16 bits words to account for pad/data frame
w 0xb103 0x1a8
```

```
w 0xb002 0x8
#write footer commands
w 0xb103 0x3000
w 0xb002 0x4
w 0xb103 0x8001
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x0007
w 0xb002 0x4
w 0xb103 0x3000
w 0xb002 0x4
w 0xb103 0x8001
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x000D
w 0xb002 0x4
w 0xb103 0x2000
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
w 0xb103 0x2000
w 0xb002 0x4
w 0xb103 0x0000
w 0xb002 0x4
```

Table 6.4: rcu-sh script commands for reading out a single frame via the SelectMAP interface. This example is for frame address 0x00060400 which is BA:00, MJA:3 and MNA:2.

A single frame consists of 106 words of 32 bits. In order to account for the internal frame buffer in the SelectMAP interface, it is necessary to first read back one extra frame which is known as a pad frame. Since the DCS-RCU interface is a 16 bit interface this means that 106 x 2 = 212 words of 16 bits must be read back for one frame.

After executing the script in Table 6.4 the both the pad frame data and frame data is available from the SelectMAP internal RAM memory in the Actel. To read out a formatted version of the frame data type the commands in Table 6.5.

Command	Description
`rcu-sh r 0xb4d4 –f %b2 -o framefile.hex`	Write binary data to a file
`od –x framefile.hex`	View the file

Table 6.5: Commands for reading out formatted frame data

6.3 Architecture of External Flash Device

Data-location	Function
Configuration pointer Scrubbing pointer Read Frame pointer Default mode pointer *(NOT USED)*	**Pointer space.** Each pointer is 4 bytes (2 word addresses). The different pointers points to addresses where more information is stored.
Configuration data start (word)-address Configuration data stop (word)-address	**Info space:** Start and stop address for initial configuration data stream. The addresses are given in word addresses
Scrubbing data start (word)-address Scrubbing data stop (word)-address	Start and stop address for scrubbing data stream. The addresses are given in word addresses
FRAME FILE INFO Start address (22 bit) Frame offset (3 bit) Number of frames (12 bit) Read frame size (8 bit) Write frame size (9 bit) Read header size (8 bit) Read footer size (8 bit)	Start address of read frame Relative address jump to next read frame Number of frames to read back Size of read frame data Size of write frame data including header/footer Size of read header Size of read footer See Table 6.7 for detailed information
Configuration data file Scrubbing data file	**File space.** The actual files are stored here. The commands needed for the Xilinx to understand the frame files are included as headers and footers in the actual files.
READ BLOCK Read – Frame header 1 Read – Data frame 1 Read – Frame Footer 1 . Read – Frame header N Read – Data frame N Read – Frame Footer N WRITE BLOCK Write – Frame header 1 Write – Data frame 1 Write – Frame Footer 1 . Write – Frame header N Write – Data frame N Write – Frame Footer N	The write frame files will always be located the address: Read-frame start address + 0x100000 Example: If the address of the first read frame 0x100000 the corresponding write frame will be located at address 0x200000.

Table 6.6: The Flash memory is divided into to three different spaces, as described below.

The Flash device is divided into to 3 different spaces:

1. *The pointer space*. This is located in the start of the Flash memory, and contains pointers to location in the info space. The addresses of the pointers are pre-defined, and a zero value in the pointer means that the given file does not exist in the Flash memory. The default mode pointer contains a pointer to one of the three other pointer locations.

2. *The info space.* This section contains the address location of the initial configuration data file and the scrubbing data file. It also contains the address location and various frame information for the frame files.
3. *The file space:* In the section of the flash all the different files are stored. That is configuration data file, the scrubbing data file and the all the frame files needed for frame by frame readback and verification (both read-frame and write-frame files)

Table 6.7 gives the detailed location of the frame related information in the flash memory. The information is stored in 16 bit words. Relative address position 0 and 1 holds the 6 MSB and 16 LSB of the read frame start address. During initial configuration address position 2 and 3 holds the stop address of the configuration data. However this information is not used during readback and verification. Further frame information is stored in the three consecutive flash address positions.

Rel. Addr.	**Content**	**Bit position**															
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	File-space start address	Not used										6 MSB					
1	File-space start address	16 LSB															
2	File-space stop address	Not used										(6 MSB)					
3	File-space stop address	Not used (16 LSB)															
4	Frame info register 1	frame offset			number of frames												*
5	Frame info register 2	read frame size - 1								write frame size - 1							
6	Frame info register 3	Read header size - 1								Read footer size - 1							
* MSB of write frame size																	

Table 6.7: Overview of frame information content in the Flash Memory Device.

6.3.1 Setting up Flash device for initial configuration and scrubbing

Example case:

- Initial configuration file *top_level.bit* of size 560751 bytes
- Scrubbing file *top_level_scrub.bit of size*

Setting up Pointer Space and Info Space

The addresses of the pointers are pre-defined, and a value of 0xFFFF in the pointer means that the given file does not exist in the Flash memory.

Pointer	**Address (BB type Flash)**
Init Config Pointer	0x000000 – Info space start address [21:16] 0x000001 – Info space start address [15:0]
Scrubbing Pointer	0x001000 – Info space start address [21:16] 0x001001 – Info space start address [15:0]
Frame pointer	0x002000 – Info space start address [21:16] 0x002001 – Info space start address [15:0]

Table 6.8: Pointers and their physical addresses in the BB type Flash Device. Please note that all pointers are in separate sectors in the Flash Memory Device, making it possible to delete only one pointer while keeping the rest. For sector addresses, look in ref 4, table "MX29LV640BT Sector Group Architecture" and column (x16) Address range.

The pointer locations contain the addresses of the respective file space information. Though these addresses can be any addresses on the Flash device it is convenient to specify some default addresses to use.

Type of info space	Start address	Type of flash
Init config	0x3000	BB
Scrubbing	0x4000	BB
Frame	0x5000	BB

Table 6.9: Default addresses of the different info spaces.

In order to setup the Info Space one must have the following information

- Start address of the files in the Flash Memory. This can be any address.
  - Start address of initial configuration file (i.e. 0x0)
  - Start address of scrubbing file (i.e. 0x50000)
  - Start address of read frame files (i.e. 0x100000)
- Stop address of the initial configuration and scrubbing file in the Flash Memory. This can be calculated from the file size and the start address. If the file is 10 bytes, it is written over 5 addresses, i.e. the stop address is:
  - 0x<stop addr> = 0x<start addr> + 0x<byte/2> – 1
- Pointer address. This is given in **Error! Reference source not found.**.

It is also important to remember the '-s' switch when writing the file to the flash memory as this swap the bytes so that they are injected in the correct order.

```
flash enable              # Enables flash mode
flash w 0x0 0x0           # set up init config pointer
flash w 0x0 0x3000        # position of start address
flash w 0x3000 0x0        # start address(21:16) of init cfg file
flash w 0x3001 0x8000     # start address(15:0) of init cfg file
flash w 0x3002 0x5        # stop address(21:16) of init cfg file
flash w 0x3003 0x2736     # stop address(15:0) of init cfg file
flash w –s 0x8000 <bitfile> # Initial configuration file.
flash w 0x0 0x0           # set up scrubbing pointer
flash w 0x1000 0x4000     # position of start address
flash w 0x4000 0x5        # start address(21:16) of scrubbing file
flash w 0x4001 0x0000     # start address(15:0) of scrubbing file
flash w 0x4002 0x7        # stop address(21:16) of scrubbing file
flash w 0x4003 0x8B88     # stop address(15:0) of scrubbing file
flash w –s 0x60000 <bitfile> # Scrubbing file
flash disable             # Disables flash mode
```

Figure 6-2: Script for setting up initial configuration file and scrubbing file on Flash Memory Device with pointer and start and stop addresses.

6.3.1.1 Sector Addresses in Flash Memory Device

This information is extracted from ref. 4, table MX29LV640BB Sector Group Architecture on page 6.

Sec.	Address range (hex)	Sec.	Address range (hex)	Sec.	Address range (hex)
0	*0 – FFF*	45	130000 – 137FFF	90	298000 – 29FFFF
1	*1000 – 1FFF*	46	138000 – 13FFFF	91	2A0000 – 2A7FFF
2	*2000 – 2FFF*	47	140000 – 147FFF	92	2A8000 – 2AFFFF
3	*3000 – 3FFF*	48	148000 – 14FFFF	93	2B0000 – 2B7FFF
4	*4000 – 4FFF*	49	150000 – 157FFF	94	2B8000 – 2BFFFF
5	*5000 – 5FFF*	50	158000 – 15FFFF	95	2C0000 – 2C7FFF
6	*6000 – 6FFF*	51	160000 – 167FFF	96	2C8000 – 2CFFFF
7	*7000 – 7FFF*	52	168000 – 16FFFF	97	2D0000 – 2D7FFF
8	8000 – FFFF	53	170000 – 177FFF	98	2D8000 – 2DFFFF
9	10000 – 17FFF	54	178000 – 17FFFF	99	2E0000 – 2E7FFF
10	18000 – 1FFFF	55	180000 – 187FFF	100	2E8000 – 2EFFFF
11	20000 – 27FFF	56	188000 – 18FFFF	101	2F0000 – 2F7FFF
12	28000 – 2FFFF	57	190000 – 197FFF	102	2F8000 – 2FFFFF
13	30000 – 37FFF	58	198000 – 19FFFF	103	300000 – 307FFF
14	38000 – 3FFFF	59	1A0000 – 1A7FFF	104	308000 – 30FFFF
15	40000 – 47FFF	60	1A8000 – 1AFFFF	105	310000 – 317FFF
16	48000 – 4FFFF	61	1B0000 – 1B7FFF	106	318000 – 31FFFF
17	50000 – 57FFF	62	1B8000 – 1BFFFF	107	320000 – 327FFF
18	58000 – 5FFFF	63	1C0000 – 1C7FFF	108	328000 – 32FFFF
19	60000 – 67FFF	64	1C8000 – 1CFFFF	109	330000 – 337FFF
20	68000 – 6FFFF	65	1D0000 – 1D7FFF	110	338000 – 33FFFF
21	70000 – 77FFF	66	1D8000 – 1DFFFF	111	340000 – 347FFF
22	78000 – 7FFFF	67	1E0000 – 1E7FFF	112	348000 – 34FFFF
23	80000 – 87FFF	68	1E8000 – 1EFFFF	113	350000 – 357FFF
24	88000 – 8FFFF	69	1F0000 – 1F7FFF	114	358000 – 35FFFF
25	90000 – 97FFF	70	1F8000 – 1FFFFF	115	360000 – 367FFF
26	98000 – 9FFFF	71	200000 – 207FFF	116	368000 – 36FFFF
27	A0000 – A7FFF	72	208000 – 20FFFF	117	370000 – 377FFF
28	A8000 – AFFFF	73	210000 – 217FFF	118	378000 – 37FFFF
29	B0000 – B7FFF	74	218000 – 21FFFF	119	380000 – 387FFF
30	B8000 – BFFFF	75	220000 – 227FFF	120	388000 – 38FFFF
31	C0000 – C7FFF	76	228000 – 22FFFF	121	390000 – 397FFF
32	C8000 – CFFFF	77	230000 – 237FFF	122	398000 – 39FFFF
33	D0000 – D7FFF	78	238000 – 23FFFF	123	3A0000 – 3A7FFF
34	D8000 – DFFFF	79	240000 – 247FFF	124	3A8000 – 3AFFFF
35	E0000 – E7FFF	80	248000 – 24FFFF	125	3B0000 – 3B7FFF
36	E8000 – EFFFF	81	250000 – 257FFF	126	3B8000 – 3BFFFF
37	F0000 – F7FFF	82	258000 – 25FFFF	*127*	3C0000 – 3C7FFF
38	F8000 – FFFFF	83	260000 – 267FFF	*128*	3C8000 – 3CFFFF
39	100000 – 107FFF	84	268000 – 26FFFF	*129*	3D0000 – 3D7FFF
40	108000 – 10FFFF	85	270000 – 277FFF	*130*	3D8000 – 3DFFFF
41	110000 – 117FFF	86	278000 – 27FFFF	*131*	3E0000 – 3E7FFF
42	118000 – 11FFFF	87	280000 – 287FFF	*132*	3E8000 – 3EFFFF
43	120000 – 127FFF	88	288000 – 28FFFF	*133*	3F0000 – 3F7FFF
44	128000 – 12FFFF	89	290000 – 297FFF	*134*	3F8000 – 3FFFFF

Table 6.10: Sector addresses in the BB type Flash Device. To erase a sector, address the start address of the sector you want to erase. The first sectors given with grey background (sec 0 – 7) are smaller sectors in the boot partition of the Flash. These sectors are used as the pointer space (and most often as info space) in the application.

6.4 Prerequisites of Active Partial Reconfiguration

The RCU consist of a Xilinx Virtex-2 Pro vp7, with an Actel device communicating with the Selectmap Interface of the Xilinx FPGA. The firmware inside the Actel has the possibility to both read and write to the configuration logic using slave selectMAP mode.

The Actel firmware supports main features:

- To read back all block num 0 and block num 2 frames continuously and overwrite any of these if an error is seen. The frames are first read back in a controlled setup and stored to be used as comparison.
- Use the active partial reconfiguration file generated by ISE to continuously overwrite the configuration memory.

To be able to do this some precautions needs to be made at design time of the Xilinx design:

1. The input LUT of the Slices cannot be used as writable memory elements. Practically this means to unselect 'shift register extraction' under HDL options in the Synthesis menu, as well as choosing to extract memory elements to BRAM..
2. The first BRAM major frame must not be used. Practically this is to not use the very first BRAM slices, which is done by the use of the CONFIG PROHIBIT argument in the ucf file (as shown below).

```
CONFIG PROHIBIT = RAMB16_X0Y9;
CONFIG PROHIBIT = MULT18X18_X0Y9;
CONFIG PROHIBIT = RAMB16_X0Y8;
CONFIG PROHIBIT = MULT18X18_X0Y8;
CONFIG PROHIBIT = RAMB16_X0Y7;
CONFIG PROHIBIT = MULT18X18_X0Y7;
CONFIG PROHIBIT = RAMB16_X0Y6;
CONFIG PROHIBIT = MULT18X18_X0Y6;
CONFIG PROHIBIT = RAMB16_X0Y5;
CONFIG PROHIBIT = MULT18X18_X0Y5;
CONFIG PROHIBIT = RAMB16_X0Y4;
CONFIG PROHIBIT = MULT18X18_X0Y4;
CONFIG PROHIBIT = RAMB16_X0Y3;
CONFIG PROHIBIT = MULT18X18_X0Y3;
CONFIG PROHIBIT = RAMB16_X0Y2;
CONFIG PROHIBIT = MULT18X18_X0Y2;
CONFIG PROHIBIT = RAMB16_X0Y1;
CONFIG PROHIBIT = MULT18X18_X0Y1;
CONFIG PROHIBIT = RAMB16_X0Y0;
CONFIG PROHIBIT = MULT18X18_X0Y0;
```

3. The selectMAP pins must be set to persist.
4. Bit files should be generated using the following bitgen commands:
    a. Initial configuration file:
    bitgen -w -d -g Persist:Yes Xilinx_RCU_FW_190606/rcu.ncd rcu.bit
    b. Active partial reconfiguration (scrubbing) file:
    bitgen -w -d -g Compress -g Persist:Yes -g ActiveReconfig:Yes -g PartialMask0:7fffffffff -g PartialMask1:0 -g PartialMask2:3F Xilinx_RCU_FW_190606/rcu.ncd rcu_apr.bit